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Art. IV.—*Observations on Saw-flies of the Genus Perga, with Notes on some reared Primary Parasites of the Families Trigonalidae, Ichneumonidae, and Tachinidae.*

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(With Plates IV. and V.)

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In a previous paper (11) details are recorded of emergences from four broods of saw-fly larvae of the genus *Perga*. It was not realized then that delayed emergences occurred, and further saw-flies and parasites subsequently emerged from three of the broods (Broods 1, 2, and 4). The total emergences are now recorded, together with identifications of the species. The saw-fly reared from Brood 2 was a new species, *Perga nemoralis* Wilson (14), with marked sexual dimorphism. Results of emergences from other broods are also recorded, the conditions of isolation of these "captive" broods being similar in all cases.

The details of emergences from the different broods forms the second section of this paper. It is preceded by a general account of the history of saw-fly development from the time the fully-grown larva enters the soil, for cocoon-spinning, to the emergence of the adult. This is desirable as discrepancies have appeared in accounts of this portion of the life-history: Froggatt (5, 6) has apparently confused the stages of a parasite (probably an Ichneumonid) with those of the saw-fly. By removing the cocoons from the soil, examining them from time to time, and noting the contents of cocoons from which emergences have occurred, a correct idea of the order of development has been obtained. This sequence of events is important for the interpretation of the meaning of exuviae or "remains," found in cocoons under examination, especially with a parasitized brood.

The third section comprises notes on three types of primary parasites, bred from "captive" broods of saw-flies, viz., Trigonalidae, Ichneumonidae, and Tachinidae. The existence of a Trigonalid as a primary parasite is noteworthy, as the Trigonalidae have hitherto been recorded only as secondary parasites.

Section A.—Life-history of the Saw-flies from Time of Entering the Soil for Cocoon-spinning to Emergence of the Adult.

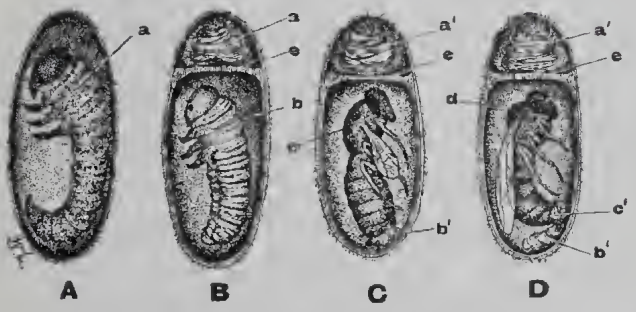
From an examination of cocoons removed from the soil, the following four stages have been identified, and are represented diagrammatically in Fig. 1:—

A. Cocoon containing the "above-ground" larva: cocoon weak or incomplete at top.

B. Cocoon containing the prepupa, the larval exuvia being shut off at top of cocoon.

C. Cocoon containing pupa, with prepupal exuvia adhering.

D. Cocoon containing adult, with exuviae of prepupa and pupa.



Text-fig. 1.—Diagram showing metamorphosis of saw-fly. (*a*), Larva; (*a*^{1}), Exuvia of larva; (*b*), Prepupa; (*b*^{1}), Exuvia of prepupa; (*c*), Pupa; (*c*^{1}), Exuvia of pupa; (*d*), Adult; (*e*), Partition.

These four stages indicate the following sequence of events in the life-history after the cessation of feeding:—The fully-fed larva enters the soil and spins an oval cocoon, weak or incomplete at the top. The cocoon is firm, of a silky texture mixed with sand, and more or less "glazed" in appearance inside—Text-fig. I A. They are generally massed together from 1 to 3 inches beneath the surface of the soil. Almost immediately after cocoon-spinning, the larva moults or changes to the *prepupal* stage, the cast skin being left at the top of the cocoon. A firm flat partition is then formed near the top, shutting off the larval exuvia—Text-fig. 1 B. The partition is a closely woven meshwork appearing more or less lace-like from above. The inner walls of the cocoon are apparently "glazed" still further by the prepupa, the glazing being continued over the lower surface of the partition. The prepupa is larval in appearance, but compared with the above-ground larva, is shorter and more compact, with a softer and lighter-coloured body. The folds of the body wall are more pronounced, the legs are shorter, and owing to the lighter colour of the head, the single black ocellus is conspicuous on either side (Pl. IV., Fig. 1). There is no external indication of wings. The prepupa can apparently change its position while glazing the inner walls (Pl. IV., Fig. 2). The usual position of rest appears to be with the head at the top of the cocoon. Without entering into the minute differences in structure of the cocoon-spinning larva and the prepupa, it may suffice to mention the differences in the mandibles, as these are useful in determining the nature of the exuviae or "remains" found in cocoons. The mandibles of the larva are hard and heavily chitinized throughout, dark brown or black, and bluntly toothed,

(Pl. V., Fig. 9). The mandibles of the prepupa are much less heavily chitinized, especially at their outer or lateral margins; they are yellowish, with the cutting edges dark brown, the latter furnished with sharply-pointed teeth (Pl. V., Fig. 10). The cutting edges of the right and left mandibles differ slightly from each other in both stages.

After a varying period, which may be very prolonged, ecdysis occurs, and the pupal stage is revealed, the prepupal exuvia adhering to the hinder abdominal region of the pupa—Text-fig. 1 C. The pupa is soft and whitish at first, darkening later, and has the head region placed against the flat partition of the cocoon (Pl. IV., Figs. 3 and 4). The pupal stage is probably very short. At the next ecdysis the fully-formed adult is revealed (Pl. IV., Fig. 5), the thin transparent exuvia being pushed to the bottom of the cocoon, where it is seen along with the old prepupal exuvia—Text-fig. 1 D. The pre-pupal and pupal exuviae often appear to be cemented together, no doubt by the moulting fluid, and by the movements of the adult. They can easily be separated and identified, after soaking for a short time in a weak potash solution.

To emerge from the cocoon, the adult cuts the partition in a more or less neat circle at the top. It is very active and capable of strong flight immediately.

The above facts show that in normal healthy broods of saw-flies, complete or unopened cocoons should contain either the saw-fly larva, or one of the three subsequent stages (prepupa, pupa, or adult), along with the exuviae of their previous instars. "Opened" cocoons, i.e., those from which emergences have occurred naturally, should contain the exuviae of all stages. These are to be found generally inside the cocoon mixed with loose sand which has fallen in when the adult was emerging.

In cases where cocoons are found to contain stages other than those mentioned above, parasites are present. A careful examination is necessary to determine the relationship of the parasite to the host.

Notes on the Prepupa and Pupa.

The prepupal stage refers to the stage interpolated between the fully-fed larva and the pupa. In the case of *Perga* sp., it is the larva-like, non-feeding form enclosed in the cocoon, and is the stage following the fully-fed cocoon-spinning larva. It is referred to as the "ultimate" larval stage by MacGuillivray(7). In some cases, this prepupal stage apparently spins the cocoon: thus Middleton(8) says "the prepupa, or seventh larval instar, is the non-feeding cocoon-spinning stage in which the larvae search out a suitable place to spend their quiescent period"; and Miles (9) notes, regarding saw-flies infesting Ribes, that the prepupal stage forms the cocoon.

In all cases, however, the prepupa is the stage which "lasts over" for varying periods before changing to the pupal stage.

In captivity the duration of the prepupal period varies considerably in the case of *Perga* sp., even in individuals of the same brood. Where larvae have entered the soil in the spring, emerging as adults towards the end of the following summer, as exemplified in Broods 1, 2, and 4, it is probable that nearly the whole of this period was spent as a prepupa, viz., between four and five months. In those broods where further emergences occurred at the end of the *second* summer (as in Broods 1 and 2), the prepupa would "last-over", the prepupal period being probably between sixteen and seventeen months. *Indirect* evidence of the existence of this long prepupal stage is obtained from examination of cocoons of "captive" broods from time to time, from the frequency with which the prepupal stage is found. The writer has obtained direct evidence of a prolonged prepupal period in three individual cases; the most noteworthy occurred in Brood 2, where the saw-fly remained in the prepupal stage for nearly four years. The other two cases are those of prepupae living for three years and four months, and for two years at least (Broods 1 and 10). Details of these cases are as follows:—

Case 1. *Prepupal Period*—3 years, 11 months: Brood 2.

Perga nemoralis Wilson (see Section B). Larvae entered the soil on 16th October, 1928: emergences occurred, during March and April, 1929, and again in March, 1930. On February 24th, 1932, as no further emergences had occurred, the cocoons were removed from the soil and examined; one contained a living prepupa. This prepupa had then lived for 3 years and 4 months. The cocoon was placed in a gelatine capsule supported in damp sawdust, and kept isolated for further observation. The prepupa was alive on 14th September, 1932, i.e., after a period of 7 months, bringing its total existence in this stage to 3 years and 11 months. Owing to the growth of moulds later, it died. This appears to be a record of longevity.

Case 2. *Prepupal Period*—3 years, 4 months: Brood 1.

Perga dorsalis Leach (see Section B). Larvae entered the soil 9th October, 1928: emergences occurred during March and April, 1929, and in April, 1930. Cocoons were examined on 24th February, 1932, i.e., 3 years and 4 months after being spun, a living prepupa was found in one. In June, 1932, this prepupa was found dead, being attacked by mites and moulds.

Case 3. *Prepupal Period*—2 years at least. Brood 10.

Perga polita Leach. Three larvae entered the soil on 16th October, 1930. On February 24th, 1932, no emergences having occurred, the cocoons were removed for examination. One was opened, revealing a prepupa, the other two were kept intact. The opened cocoon was tied round with cotton and replaced, with the other two, in the soil. In July they were again examined; the prepupa was living, and had repaired the hole previously made in the cocoon wall. The cocoons were now placed in separate phials plugged with cotton-wool and supported in damp sawdust. On 26th October, 1932, an adult female emerged from one of the previously unopened cocoons; examination of the previously opened cocoon showed that the prepupa was living and apparently healthy, that is, after a period of at least two years. In March, 1933, the prepupa was found dead, owing to attack by mites and moulds. In July, 1933, when the third cocoon was opened a developed female was found infested with moulds. No doubt it should have emerged during the previous March or April.

There appears to be no previous record of this prolonged prepupal period for Australian saw-flies. Of British species, Cameron (1) mentions the possibility of a period of two years in the cocoon before changing into the pupa, though he does not seem to recognize a prepupal instar. He says: " When the larva has become full fed it proceeds to pupate. Some larvae spin no cocoon . . . . but most species spin oblong silken cocoons. After being in the cocoon the larva in a short time shortens and contracts its shape, the legs at the same time being withdrawn into the skin as it were. The period which elapses between the spinning of the cocoon and becoming a pupa varies according to the season. With the summer broods it may be seven to ten days, but the autumnal broods do not change until the following spring, so that the greater part of their larval existence is spent in this inert condition. In exceptional cases they may remain two years in the cocoon before changing."

Dealing with *Dielocerus formosus* Klug, da Costa(2) refers to the probable oestivation of the larva in the cocoon, for at least three years. Apparently, however, these cocoons had not been isolated or kept under quarantine conditions during that period.

The duration of the pupal stage is probably very short, and is easily overlooked. Pupae found in cocoons opened for examination, being soft and delicate, are easily damaged, and fail to metamorphose. As other broods become available for examination, it is hoped to determine the length of this pupal period. Cameron(1) remarks that the pupal state does not last over 12 or 14 days, as a rule, and may be shorter.

The well-developed pupae shown in Plate IV., Fig. 4, were found within three months of the larvae entering the soil. As the details available to date for this brood of larvae (Brood 46) are not shown in Section B, they are noted as follows:—Larvae, collected at Healesville by Mr. H. G. Andrewartha, entered the soil on 27th November, 1933: cocoons were opened and these pupae exposed on 16th February, 1934: on 21st February the pupal skins were cast, revealing adults of *Perga dorsalis* Leach.

Section B.—Results of Emergences from captive Broods of Saw-fly Larvæ.

The following details are results of emergences from different broods of larvae, collected from time to time, and kept isolated for observation. The main object in view at first was to determine the proportion of sexes emerging from the various broods, and this has been set out in each case. Owing, however, to frequent internal parasitism of the larvae when collected, this has been masked in most cases. Parasitism is frequent, particularly by Tachinid flies.

Another object in view was to associate the larvae with the adults for identification. When the various larvae were collected, a few were preserved in alcohol, with the brood number attached, while others were allowed to enter the soil.

The dates have been shown for each brood, these being important, especially in regard to the relative times of emergence of males and females. Though no generalization can be made from the data, the females appear to preponderate, and males are the earliest to emerge. The "lasting-over" of both saw-flies and parasites is also shown for some of the broods.

The conditions in captivity were as follows:—The different broods were placed on soil in flower-pots covered with hurricane lamp chimneys or fly-wire covers. In most cases, the pots have been buried in soil in larger glazed pots, and by keeping the soil in these moist, suitable conditions have been maintained in the inner pots. These have been kept in the Insectary at the School of Agriculture, University of Melbourne.

Brood 1. *Perga dorsalis* Leach.

Larvae collected by Mr. G. F. Hill, at Warrandyte, Victoria, October.

9th October, 1928.—34 larvae entered soil for cocoon-spinning.

Emergences occurred as follows:—

15th March, 1929.—1 saw-fly (male).
8th April, 1929.—5 saw-flies (females).
29th August, 1929.—5 Tachinid flies.

13th September, 1929.—1 Tachinid fly.
8th April, 1930.—1 saw-fly (male).
16th April, 1930.—1 saw-fly (female).
22nd April, 1930.—1 saw-fly (male).
16th September, 1930.—1 Tachinid fly.
22nd September, 1930.—1 Tachinid fly.

Total Emergences.—Three male and six female saw-flies and eight Tachinid flies.

24th February, 1932.—In cocoons opened for examination, ten developed female saw-flies, apparently unable to emerge from the cocoons, were found; also a living prepupa.

Brood 2. *Perga nemoralis* Wilson.

Larvae collected by the writer at Wonga Park (South Warrandyte), Victoria, October, 1928.

16th October, 1928.—Larvae entered soil.

Emergences occurred as follows:—

14th March, 1929.—2 saw-flies (1 male and 1 female).
20th March, 1929.—3 saw-flies (females).
1st April, 1929.—2 saw-flies (females).
9th April, 1929.—1 Tachinid fly.
24th March, 1930.—1 saw-fly (male).
27th March, 1930.—2 saw-flies (1 male and 1 female).
28th March, 1930.—2 saw-flies (1 male and 1 female).
30th March, 1930.—3 saw-flies (females).
31st March, 1930.—1 saw-fly (female).
17th April, 1930.—1 Tachinid fly.
1st May, 1930.—1 Tachinid fly.

Total Emergences.—Four male and twelve female saw-flies, and three Tachinid flies.

24th February, 1932.—On examination of cocoons removed from soil, one was found to contain a living prepupa.

Brood 3. *Perga polita* Leach.

Larvae collected, by the writer, at Blackburn, Victoria, October, 1928; 19 larvae entered the soil almost immediately.

Details of emergences have already been given (11).

Total emergences were as follows:—During March and April, 1929, sixteen female saw-flies emerged.

Brood 4. *Perga dorsalis* Leach.

Larvae collected by the writer at Eltham, Victoria, September, 1929.

11th October, 1929.—16 larvae entered soil.

Emergences ocurred as follows:—

12th December, 1929.—5 Tachinid flies.
13th December, 1929.—1 Tachinid fly.
14th December, 1929.—1 Tachinid fly.
16th December, 1929.—1 Tachinid fly.
18th February, 1930.—1 Tachinid fly found dead (actual date of emergence not known).
28th March, 1930.—1 saw-fly (female).
30th March, 1930.—1 saw-fly (female).
2nd April, 1930.—2 saw-flies (females).
5th April, 1930.—1 saw-fly (male).
8th April, 1930.—1 saw-fly (female).
12th July, 1930.—1 Tachinid fly.

Total Emergences.—One male and five female saw-flies, and ten Tachinid flies.

Brood 14. *Perga dorsalis* Leach.

Larvae collected Eltham, Victoria, October, 1931.

17th October, 1931.—35 larvae entered soil.

Emergences occurred as follows:—

19th February, 1932.—Two cocoons were removed from the soil and opened—found to contain prepupae.
18th March, 1932.—5 saw-flies females).
19th March, 1932.—2 saw-flies (1 male and 1 female).
21st March, 1932.—3 saw-flies (females).
23rd March, 1932.—1 saw-fly (female).
Total Emergences.—One male and ten female saw-flies.

Examination of cocoons on 30th May, 1932, yielded the following results:—

11 cocoons contained saw-fly exuviae only, and represented those from which saw-fly emergences had already occurred.
2 cocoons contained dead prepupae.
5 cocoons were not opened.
13 cocoons contained 18 Tachinid parasites (larvae and puparia) with remains of saw-fly prepupae.

Brood 16. *Perga dorsalis* Leach.

Larvae collected, by the writer, Healesville, Victoria, December, 1931.

23rd December, 1931.—22 larvae entered the soil.

Emergences occurred as follows:—

15th February, 1932.—1 Tachinid fly (female).
29th February, 1932.—1 saw-fly (male).
1st March, 1932.—1 saw-fly (male).

3rd March, 1932.—1 Tachinid fly (female).
4th March, 1932.—3 saw-flies (females).
8th March, 1932.—1 saw-fly (female).
10th March, 1932.—1 saw-fly (female).
29th March, 1932.—1 Tachinid fly.

Total Emergences.—Two male and five female saw-flies, and three Tachinid flies.

This is the shortest period noted for complete metamorphosis.

Examination of cocoons on 9th July, 1932, yielded the following results:—

7 cocoons contained saw-fly exuviae only, and represented those from which emergences had occurred.

3 cocoons each contained a prepupa (two dead, and one living; from the latter a female emerged between March and May, 1933).

1 cocoon contained a dead adult saw-fly, enveloped in its pupal membrane.

6 cocoons contained Tachinid parasites (two of these were subsequently bred out—emerging in September, 1933.)

2 cocoons each contained an Ichneumonid cocoon.

Brood 22. *Perga dorsalis* Leach.

Larvae collected by Miss J. Robertson, at Eltham, Victoria, October, 1932.

25th October, 1932.—About 16 larvae entered soil.

Emergences occurred as follows:—

7th March, 1933.—1 saw-fly (male).
16th March, 1933.—1 saw-fly (male).
17th March, 1933.—1 saw-fly (female).
23rd March, 1933.—2 saw-flies (females).
24th March, 1933.—1 saw-fly (male).
27th March, 1933.—1 saw-fly (female).
8th August, 1933.—1 Tachinid fly (male).
12th August, 1933.—1 Tachinid fly (female).
23rd August, 1933.—1 Tachinid fly (female).
28th August, 1933.—1 Tachinid fly (female).
30th August, 1933.—1 Tachinid fly (male).
5th September, 1933.—1 Tachinid fly (female).
18th September, 1933.—1 Tachinid fly (female).
19th September, 1933.—1 Tachinid fly (male).

Total Emergences.—Three male and four female saw-flies, and eight Tachinid flies.

Brood 23. *Perga dorsalis* Leach.

Large mass of larvae, collected by Mr. K. M. Ward, at Mooroopna, Victoria, October, 1932.

26th October, 1932.—Larvae entering soil.

Emergences were as follows:—

28th March, 1933.—2 saw-flies (1 male and 1 female).
30th March, 1933.—3 saw-flies (females).
3rd April, 1933.—3 saw-flies (females).
4th April, 1933.—14 saw-flies (4 males, and 10 females).
5th April, 1933.—4 saw-flies (1 male and 3 females).
6th April, 1933.—3 saw-flies (1 male and 2 females).
10th April, 1933.—1 saw-fly (female).
3rd May, 1933.—6 Trigonalids (females).
8th May, 1933.—1 Trigonalid (female).
9th May, 1933.—2 Trigonalids (females).
(?) May, 1933.—1 Trigonalid (female).
(?) May, 1933.—Cocoons were examined—1 dead Trigonalid female found.

Total Emergences.—Seven male and twenty-three female saw-flies, and eleven female Trigonalids.

(A large number of this brood died during moulting.)

Brood 24. *Perga nemoralis* Wilson.

Larvae, collected by the writer, at Eltham, Victoria, October, 1932.

5th November, 1932.—Larvae entered soil.

Emergences occurred as follows:—

16th March, 1933.—1 saw-fly (male).
17th March, 1933.—2 saw-flies (males).
18-20th March, 1933.—6 saw-flies (2 males and 4 females).
22-29th March, 1933.—11 saw-flies (females).
3rd April, 1933.—1 saw-fly (male).
11th April, 1933.—1 Trigonalid (female).
26th April, 1933.—2 Trigonalids (males).
26th April, 1933.—Cocoons were removed from soil, and subsequent emergences were as follows:—
27th April, 1933.—2 Trigonalids (1 male and 1 female) emerged on cocoons being opened slightly.
29th April, 1933.—1 Trigonalid (male) emerged.
29th April, 1933.—2 Trigonalids (1 male and 1 female) emerged on cocoons being opened slightly.
30th April, 1933.—1 Trigonalid (male) emerged.
27th June, 1933.—2 Ichneumonids emerged.

Total Emergences.—Six male and fifteen female saw-flies, nine Trigonalids (6 male and 3 females), and two Ichneumonids.

Examination of 17 cocoons from which emergences had not occurred yielded the following results on 28th April, 1933:—

6 cocoons each contained a prepupa.

4 cocoons each contained a Trigonalid (3 pupae and one larva, apparently decaying).

7 cocoons each contained an Ichneumonid cocoon (5 containing an Ichneumonid larva, and 2 an Ichneumonid pupa).

Section C.—Notes on Primary Parasites of Perga spp., viz., Trigonalidæ, Ichneumonidæ, and Tachinidæ.

1. Trigonalidae.

The occurrence of wasps of the family Trigonalidae emerging from "captive" broods of saw-fly larvae is of special interest; they have, until now, been shown to be secondary parasites only. It is now established that the species bred is a primary parasite on *Perga nemoralis* Wilson, and on *P. dorsalis* Leach. The specimens from both broods are identical with *Trigonalis maculatus* Sm., (= *Taeniogonalos maculatus* Sm.), in the collection of the National Museum.

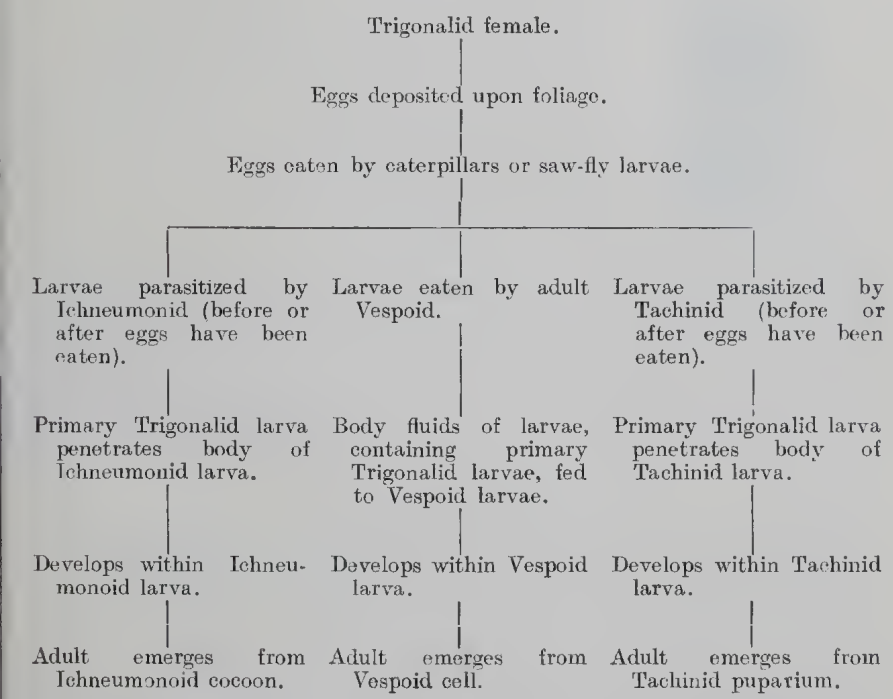
The family Trigonalidae, though small and rare, is widely distributed, only two species being known in Australia, viz., *Trigonalis maculatus* Sm., and *Mimelogonalos bouvieri* Sch. Tillyard (13) places the family in the Super-family Vespoidea, mainly on the presence of a terminal ovipositor, and the extension of the sides of the pronotum back to the tegulae. He notes, however, that "This small family appears to be intermediate between the Ichneumonoidea and typical Vespoidea, as it has the divided trochanters and many-segmented antennae of the former, whereas the ovipositor issues from the end of the abdomen, and closely resembles those of the latter, though it does not appear to be known whether it is used as a sting or not."

Other external features of the adult Trigonalid are the following:—Body brownish-black with yellowish markings; antennae with 25 segments; tarsal claws pectinate; tip of abdomen of female turned ventrally, directed towards a median process on the hinder edge of the second visible sternite. In the male, the second visible sternite has a depressed circular area in the position of the process of the female. Details of the anatomy of the family, with figures, are given by Schultz (12).

The Trigonalidae are known chiefly as secondary parasites on Vespoids and on Tachinids. Recently, however, Clausen (3) has recorded the emergence of a Trigonalid (*Poecilogonalos thwaitesii* Westw.), from cocoons of an Ichneumonid (*Henicospilus rufus* Tosq.), the latter being regarded as a parasite of a

"lepidopterous larva, probably of the Noctuidae." In this case, therefore, the Trigonalid is also a secondary parasite. In a later paper, Clausen (4) has reviewed the literature on Trigonalidae, giving the known habits of the species. From his summary all cases recorded to that time (1931) were secondary parasites only. In searching for caterpillar hosts of Ichneumonids, from which the Trigonalids emerged, Clausen secured a single saw-fly larva, which on dissection was found to contain in the body cavity three Trigonalid larvae in first stage. All his rearings of Trigonalids, however, were from cocoons of Ichneumonids, which previously parasitized some unknown phytophagous larva, that is, they were secondary parasites.

The life cycle of the Trigonalidae in the Ichneumonid, Vespoid, and Tachinid hosts, is set out by him (hypothetically in the case of Vespoids), in tabulated form, as follows:—

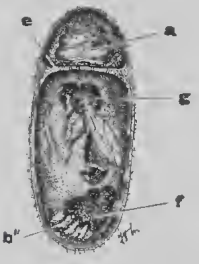


Evidence of Primary Parasitism of a Trigonalid on Perga spp.

The details of emergences show that in Brood 23 (*Perga dorsalis* Leach), the only parasites present were Trigonalids, whereas in Brood 24 (*Perga nemoralis* Wilson) parasites belonging to both Trigonalidae and Ichneumonidae appeared. An examination of the cocoons from which the Trigonalids had emerged, or which might still yield Trigonalids, was made to determine the relationship of the parasite to the saw-fly, as many of the broods of

larvae under observation had yielded Tachinid parasites. In Brood 24, where Trigonalids were present, Ichneumonid cocoons were also found in some of the saw-fly cocoons, and Ichneumonids have recently been recorded as hosts for Trigonalids.

If the Trigonalid is a *primary* parasite on the saw-fly, one would expect to find inside the host cocoons, where the Trigonalids are present (or had been), not only the larval and pupal exuviae of the Trigonalid, but also "remains" of the saw-fly larva, or prepupa, left by the parasite. If, on the other hand, it is a *secondary* parasite, then there also should be present, in the cocoon, exuviae, or "remains" of some other form representing the primary parasite. Examination of every fragment of material which might represent exuviae or "remains" of possible hosts, was made with a binocular microscope.



TEXT-FIG. 2.—Diagram showing arrangement of parts in host cocoon, when Trigonalid is present. (a^1), Exuvia of larva of saw-fly; (b^{11}), Remains of prepupa of saw-fly; (e), Partition; (f), Meconium, and exuviae of Trigonalid larva and pupa; (g), Adult Trigonalid.

Examination of cocoons of Brood 24 yielded the following results:—Trigonalids were about to emerge from four of them when opened. The adult Trigonalid was free from the pupal covering. The antennae were vibrating actively, and it immediately escaped through the hole made. It was active and capable of flight. (There was no cocoon belonging to the Trigonalid—compare Clausen (4)). After the walls of the saw-fly cocoon were sufficiently cut away, the relative position of the contents was as represented in Text-figure 2. At the top of the cocoon was a flat partition, with a saw-fly larval exuvia above. At the bottom was a compact dark-greyish mass, "livery" in appearance, surrounded by a firm membrane, with the dried remains of the saw-fly prepupa adhering to it. Two exuviae were seen to be adhering to the "livery" mass, and these, after softening slightly in weak potash, could be separated easily, and were identified as Trigonalid larval and pupal exuviae respectively. The larval exuvia is dirty white, and bears two tridentate mandibles (Plate V., Fig. 11), resembling those of the full-grown larva of the Trigonalid figured by Clausen (3). The pupal exuvia was translucent white, and showed a pair of slight bulges or papillae, which later were seen to be the portions of the pupal covering, in the region of the adult mandibles. The "livery" mass is the meconium, or material voided from the alimentary canal of the Trigonalid larva. By teasing out this meconium, numerous sharp, sickle-like mandibles (Plate V., Fig.

12) were found scattered through the mass, also minute chitinous head-capsules, an occasional one of which bore one or both mandibles. These closely resemble the heads and sharp mandibles of the earlier instars of Trigonalid larvae, as figured by Clausen (3), and no doubt represent the remains of the younger and weaker Trigonalid larvae. The remains of these competitors would be in the alimentary canal of the surviving Trigonalid larva, and therefore in the meconium, expelled at ecdysis from larval to pupal stage. These mandibles and head capsules are extremely minute and difficult to separate from the more or less brittle mass of meconium when preserved in alcohol. In some cases the whole of the meconium has not been teased out; the greatest number of head-capsules and mandibles found in any one meconium has been five of the former and nine of the latter.

Of the three cocoons which contained each a Trigonalid pupa (Brood 24), the arrangement of the contents was similar to the above four cases (with, of course, the absence of the Trigonalid pupal exuviae). In these three cases, the meconium and the Trigonalid larval exuviae were attached to the pupa, near the anus. In one case the saw-fly had metamorphosed to the pupal stage, the skin of the latter, as well as the exuvia of the prepupal stage, being found. When the five cocoons from which Trigonalids had emerged whilst in the soil were opened for examination, it was found that the contents resembled those of cocoons where Trigonalids were observed emerging. The examination revealed no indication of the presence of any form, other than the Trigonalid and the saw-fly. It is concluded, therefore, that the Trigonalid is a primary parasite on the saw-fly.

2. Ichneumonidae.

Of the various broods of larvae kept under observation, Ichneumonids have occurred in Broods 16, 24, 25, and 36. The arrangement of the contents of saw-fly cocoons, when parasitized by Ichneumonids, is somewhat similar to that described for the Trigonalid parasite, excepting that the Ichneumonid is enclosed in a cocoon within the saw-fly cocoon. Examination of these cocoons shows that the Ichneumonids are primary parasites. The usual arrangement within the host cocoon is as follows:— The saw-fly larval exuvia is at the top chamber of the cocoon, the Ichneumonid cocoon almost fills the space within the host cocoon; in most cases it was found to contain a large larva (Plate IV., Fig. 6). Where the parasites had metamorphosed to the pupal stage, the cast larval skin and the meconium were also present, adhering to the tip of the pupa. Lying on the outer side of the Ichneumonid cocoon, and flattened against the wall of the host cocoon, the remains of the saw-fly prepupa are found. In some of the cocoons it was noticed that the sieve-like partition had not been formed, the prepupa being weakened by the parasite.

In these cases, both the saw-fly larval exuvia and the remains of the prepupa were found attached to the outside of the Ichneumonid cocoon.

Though Ichneumonids have most often been found to be the only parasite present in a particular brood, it has already been indicated (Brood 24) that there was also a Trigonalid. Both these parasites have been proved to be primary in different larvae of the brood. In two cases which have come under my notice, both Ichneumonids and Tachinid flies have been found as parasites in the same brood; these, however, being primary parasites, on separate individuals.

The following details regarding the Ichneumonid parasites have been recorded from the four broods of saw-fly larvae:—

Brood 16.—From the data set out in Section B, it is seen that when the host cocoons were examined in July, 1932, two were found to contain an Ichneumonid cocoon. On opening one of these, the parasite was still in the larval stage. The Ichneumonid had thus spent at least seven months as a larva within the host cocoon.

Brood 24.—Two Ichneumonids (species not indentified) emerged on June 27th, 1933, i.e., seven months after the cocoon-spinning of the host (see data, Section B). The cocoons of these Ichneumonids had been removed from the host cocoons during April, 1933; each was supported in a phial, plugged with cotton-wool, and placed in an incubator kept at 20 deg. C.

When the host cocoons were examined in April, 1933, five Ichneumonid larvae had lived for at least five months within the host cocoon, while two others had metmorphosed to the pupal stage at the end of that time.

Brood 25.—*Perga polita* Leach. (Date not given in Section B).

15th November, 1932.—Seven saw-fly larvae, collected at Eltham by the writer, entered the soil..

4th April, 1933.—One saw-fly (female) emerged.

21st July, 1933.—One Ichneumonid (*Paniscus productus* Brulle) emerged.

The Ichneumonid emerged eight months after the cocoon-spinning of the host.

Brood 36.—Identification of saw-fly not known, as no emergences occurred. (Data not given in Section B.)

Larvae collected at Kalorama, Victoria, by Miss H. V. Steele.

10th May, 1933.—Twenty larvae entered the soil.

19th July, 1933.—Cocoons removed from soil.

Cocoon No. 1 was opened slightly and found to contain a prepupa which evidently supported an internal Ichneumonid, for on July 31st on re-examination it contained an Ichneumonid cocoon. "Remains" of prepupal saw-fly were also present.

Two others (Nos. 9 and 10) containing Ichneumonid cocoons were kept in separate phials plugged with cotton-wool, for possible emergences. These were placed in a vessel containing saturated salt solution (about 75 per cent. relative humidity) and kept at ordinary room temperature. A mass of about eight cocoons was kept under similar conditions for possible emergences.

4th December, 1933.—Male Ichneumonid (*Labium associatum* T. and W.) emerged from mass of cocoons.

2nd February, 1934.—Ichneumonid (*Eriostethus* ?sp.) emerged from cocoon No. 9.

2nd February, 1934.—Ichneumonid (not identified) emerged from cocoon No. 10.

In this brood an Ichneumonid larva (cocoon 1) fed within its host for two months before spinning its cocoon. Two Ichneumonids (cocoons Nos. 9 and 10) emerged six to seven months, at least, after spinning their cocoons, and eight to nine months after the host larva had spun.

3. Tachinidae.

In the numerous broods of *Perga* larvae held in captivity, the commonest parasite proved to be the Tachinid fly. Of the broods collected, some have failed to spin, others spun weak cocoons and died. Of 20 normal or apparently healthy broods of larvae, Tachinids were present in fourteen. Some emerged normally, others were found in cocoons removed from the soil. In these broods there was no external indication of parasitism (with the exception of one case—Brood 16—where eggs were found adhering to the skin of the fully-grown larvae). Examination of host cocoons, noting exuviae, &c., shows the Tachinid fly to be a *primary* parasite.

The early larval stages of the parasite have not been studied, nor has the association of the parasite to the host regarding attachment for respiratory purposes. The stages found have been well advanced, corresponding to those represented in Figs. 7 and 8. A prepupa has been found to support, internally, five Tachinid larvae, though the usual number appears to be one or two. On opening cocoons, the host prepupa may appear perfect, but in time the body of the prepupa becomes irregular, and appears shrivelled except where one of more parasite larvae are present. Later they leave the host and pupate within the host

cocoon (Plate IV., Fig. 8). It is noticeable that where complete puparia have been found, lying freely within the cocoon, with the shrivelled remains of the prepupa pushed to one side, the sieve-like partition at the top invariably shows an aperture or break. This partition, however, always appears complete when the parasite is within the body of the prepupa. Apparently the partition is cut by the Tachinid larva, previous to pupating, to facilitate emergence of the fly.

There is seldom any indication of the existence of these parasites when the larvae are collected, no doubt due to an ecdysis having taken place after the Tachinid eggs were laid on the body of the host. In some broods, however, where parasitism occurred it was noticed that the host cocoons were spun irregularly, i.e. more or less horizontally instead of vertically, and singly instead of in masses.

The length of time spent by the Tachinid within the host is shown in the emergence data in Section B.:—

Brood 1.—Tachinids emerged ten months after cocoon-spinning of the host, and again twelve months later.

Brood 2.—Tachinids emerged six months after cocoon-spinning, and again twelve months later.

Brood 22.—Tachinids emerged between nine and eleven months, after cocoon-spinning.

Brood 4.—Tachinids emerged two months after cocoon-spinning, and again nine months later.

Although all the larvae of these four broods spun during the same month (October), the time spent by the parasites within their host cocoons varies widely in the different broods. This might be accounted for by the fact that some broods were attacked in early larval life, while others remained free until more fully grown.

In *Broods* 1 and 2 it appears that the Tachinid may be capable of "lasting-over" for a year, as was seen to be the case in the host. From the emergences noted in *Brood* 4, one might surmise that the individual host larvae of that brood had been "struck" at varying intervals during their larval life. The individuals of this brood would, at the time of spinning, contain parasitic larvae of various ages, which would account for the irregularities noted in the times of emergences of the parasites. This might also be the case in *Brood* 16, which spun in December and emerged in February and March, and again in September. The latter emergences occurred from cocoons which had previously been removed from the soil. (Some of the larvae of this brood were noted to be carrying eggs of Tachinids.)

Brood 14.—Of the thirteen cocoons found to contain Tachinid parasites, nine contained one each, three contained two each, and one had three. Of the nine hosts with a single parasite each, four of the latter were full-grown larvae, feeding within the host prepupa; the remaining five parasites, which were beginning to darken into the puparial condition, were lying freely within their host cocoon, having apparently only recently worked their way out of the prepupa. In those four host cocoons which each carried either two or three Tachinids, the latter had already metamorphosed into the pupal stage, the darkened puparia lying freely within the cocoons. It was noticeable that where there was more than one Tachinid puparium in the cocoon, there was a big difference in their sizes.

Brood 35.—*Perga* sp. (Data not given in Section B.) Larvae collected at Kalorama, Victoria, by Miss H. V. Steele.

28th April, 1933.—Four larvae entered the soil.

19th July, 1933.—Cocoons dug up for examination.

Three cocoons were removed, and on being opened slightly were found to contain one Tachinid puparium each. The cocoons were supported in phials plugged with cotton-wool, and were stood in a vessel containing saturated salt solution (about 75 per cent. relative humidity); these were then kept in an ordinary glass-house, and the following emergences occurred:—

14th August, 1933.—One Tachinid.

25th August, 1933.—One Tachinid.

28th August, 1933.—One Tachinid.

The Tachinids emerged, in this brood, within four months from the time of cocoon-spinning of the host.

Brood 36.—*Perga* sp. (Data not given in Section B.)

10th May, 1933.—Larvae entered the soil.

19th July, 1933.—Cocoons removed for examination.

One cocoon was found which contained a large Tachinid larva within the prepupa.

31st July, 1933.—Tachinid larva exposed by cutting the saw-fly prepupa.

5th August, 1933.—Tachinid still in larval stage.

8th August, 1933.—Tachinid puparium formed.

11th September, 1933.—Still in puparium condition.

26th September, 1933.—Tachinid emerged.

The metamorphosis of the fully-grown Tachinid larva to adult stage, occupied no more than seven weeks.

Acknowledgments.

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Explanation of Plates IV. and V.

Plate IV.

(All photographs on Plate IV. are approximately natural size.)

Fig. 1.—Cocoon-spinning larva (above), and prepupa (below), of *Perga dorsalis* Leach (Brood 14).

Fig. 2.—Mass of cocoons of *Perga* sp., four of which have been cut open to show the living prepupae: and cocoon-spinning larva (preserved in alcohol) of the same brood (Brood 33).

Fig. 3.—Living prepupa and pupa of *Perga* sp. (Brood 44).

Fig. 4.—Cocoons of *Perga dorsalis* Leach, opened to expose pupae (Brood 46).

Fig. 5.—Cocoon of *Perga dorsalis* Leach, cut open to show adult ready to emerge. Note partition and larval exuvia at top of cocoon. Other exuviae not visible.

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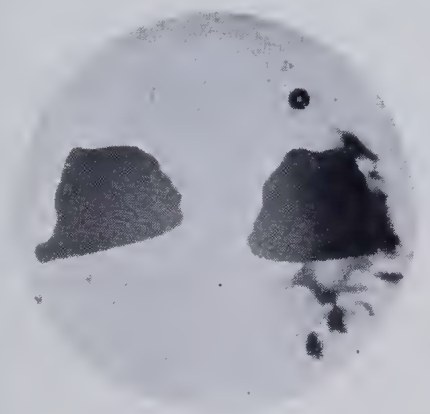
Saw-fly and Parasite.



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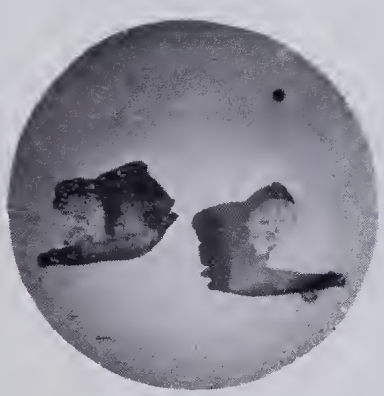

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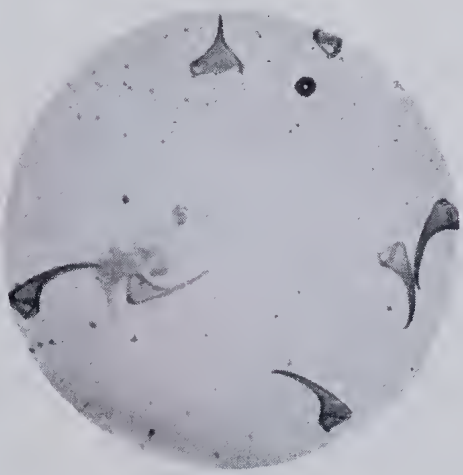

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Saw-fly and Parasite.

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Fig. 6.—Cocoons of *Perga* sp. (Brood 36) opened to show Ichneumonid primary parasite: right, Ichneumonid cocoon in position; left, Ichneumonid larva removed from its cocoon.

Fig. 7.—Mature larva of Tachinid fly exposed by cutting open shrivelled prepupa of *Perga* sp. (Brood 36).

Fig. 8.—Puparial shells of Tachinid fly, exposed by cutting open cocoon of *Perga* sp.

PLATE V.

Fig. 9.—Photomicrograph of mandibles of cocoon-spinning larva of *Perga nemoralis* Wilson (Brood 24). × 15.

Fig. 10.—Photomicrograph of mandibles of prepupa of *Perga nemoralis* Wilson (Brood 24). × 15.

Fig. 11.—Photomicrograph of portion of exuvia of mature larva of *Trigonalis maculatus* Sm., showing tri-dentate mandibles. × 29.

Fig. 12.—Photomicrograph of sickle-like mandibles of early instars of *Trigonalis maculatus* Sm. larvae, teased out from meconium of a mature larva of same. × 29.